Chapter

Effects of the Incorporation of Arabinoxylans Derived from Selected Cereals (Rice Bran and Corn Fibre) and Sugarcane Bagasse on the Quality of Baked Foods: A Systematic Review

Roy Orain Porter

Abstract

The supplementation of baked foods, namely cookie/biscuits, bread and cakes with agricultural by-products from cereal based fibres (rice bran and corn fibre) and sugarcane bagasse at rates of 0% - 15%; 0% - 30% and 0% - 10% respectively can significantly improve its nutritive value and enhanced its physical and sensorial qualities. This chapter aims to review the role of dietary fibres derived from selected cereals (rice bran and corn fibre) and sugarcane bagasse in baked foods, namely cookies/biscuits, bread and cakes; evaluate their effects on the physical and sensory qualities of these baked food products and to critically assess their beneficial impacts in baked foods. These enriched food products can potentially be utilised in shaping health policies, contribute to the dietary fibre needs of consumers and facilitate the development of functional foods. Fibre enriched foods potentially can assist in improving various physiological functions of the human body. A Keyword-based search strategy was utilised to conduct a comprehensive search for articles catalogued in ScienceDirect, Web of Science, PubMed, Medline, CINAHL and Google Scholar that were published between January 1, 2010 and August 1, 2020. Applicable aspects of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines provided the framework of this review. Fourteen (14) studies met the inclusion/extraction criteria and was placed into subgroups by food types and fibre used in supplementation. Only eleven (11) studies were suitable for statistical data analysis. The supplementation of sugarcane bagasse at both 5% and 10% and rice bran up to 15% into cookies/biscuits significantly undesirable acceptance ($p < 0.05$). Corn fibre enriched cookies/biscuits up to 20% showed a significantly ($p < 0.05$) favourable impact on the sensory qualities of the food product. The physical qualities of sugarcane bagasse supplemented cookies/biscuits were negatively affected. The incremental addition of sugarcane bagasse resulted in at 50% rise in the firmness of 10% enriched cookies/biscuits, from 5.7 ± 5.4 (Kg Force) to 13.0 ± 3.9 (Kg Force). Corn fibre cookies supplementation did not significantly affect its physical qualities. Rice bran incorporation of 15% in bread showed a significant ($p < 0.05$) undesirable effect on its sensory qualities. However, the was no significant adverse effect on its physical quality. Corn bran

enriched cakes up to 20% fibre incorporation displayed a significant ($p < 0.05$) favourable effect on the sensory properties of cakes.

Keywords: Arabinoxylans incorporation, dietary fibres, rice bran, corn fibre, sugarcane bagasse, baked food products

1. Introduction

There are numerous dietary fibre enriched food products developed in the food industry during the last decade encompassing various popular and widely consumed foods such as bread, cakes, cookies or biscuits, yoghurts among others [1–4]. It is well established in the literature, that dietary fibre intake at levels greater than 25 g per day, tend to be associated with numerous health benefits, namely the reduced risk of coronary heart disease, type 2 diabetes, enhanced physiological functions of the human body, improved weight maintenance and other positive effects on various disease risk factors and the alleviation of certain types of cancers [5–8].

In recent years, several drivers such as consumer awareness of the nutritional value of dietary enriched foods, and governmental policies promoting healthy lifestyle behaviours have contributed to the continual increase in the use of dietary fibres in foods [3, 9–11]. Consequently, the value of the dietary fibres global market is expected to experience an astonishing annual rise, with the latest estimates projected growth of about 9.74 billion U.S. dollars by 2025 [12]. Dietary fibres can be considered as non-digestible carbohydrates which are inclusive of lignin, resistant oligosaccharides, resistant starch, non-starch polysaccharides (NSP) such as cellulose, pectins, hydrocolloids and hemicelluloses of which can be eaten and are not prone to enzymatic digestion and absorption within the small intestines, but can undergo complete or partial fermentation in the large intestine of the human body [1, 3, 6]. In previous studies, Foschia, Peressini, Sensidoni, and Brennan [13] indicated that the major dietary fibres (DFs) are consist of arabinoxylans, β-glucans, resistant starch and inulin. In the non-starch polysaccharides (NSP) fraction, arabinoxylan is the main polysaccharide, additionally, arabinoxylan structure is comprised of a framework of β-(1–4) connected xylose residues to which α-L-arabinose tend to linked unto the second or third carbon positions [14, 15]. Agricultural by-products from milling industries namely fibres from selected cereal crops rice, corn, and energy crop sugarcane and plant parts from other fruits and vegetables can be regarded as dietary fibres and subsequently tend to contain arabinoxylans in varying amounts [16–18]. The addition of fibres to food products tends to influence the consistency, texture, rheological tendencies and sensory characteristics of the finished food products [3]. The incorporation of fibres in breakfast cereals, bread, cookies, cakes, pasta, yogurt, beverages and meat products among others have been widely reported with desirable results [2, 13, 19–23].

Arabinoxylans have been considered as an important dietary fibre of selected cereals (rice bran and corn fibre) and sugarcane bagasse and it has been suggested that when incorporated in the optimum proportions into food products they are capable of improving its quality, which includes, but not limited to only changes in the physical, rheological, and sensorial characteristics of food products [24–26]. Moreover, various technological functions of food products are also enhanced by dietary fibre incorporation into foods such as its nutritional value, functional properties and improvement of other chemical properties [27–29]. It has also been reported in several studies that dietary fibre arabinoxylans from agricultural by-products such as rice bran, corn fibre: brans and other corn parts and sugarcane bagasse can be safely utilised in the baking industry and consequently be used whole or as extracts of soluble dietary arabinoxylans to facilitate the production of functional and health-promoting food products through the supplementation of bread, cakes, cookies and other food products at varying incorporation rates [2, 17, 30–34].

However, there is a lack of consensus in the body of literature relating to the beneficial effects the incorporation at various levels of dietary arabinoxylans derived or originating from sources such as selected rice bran, corn fibre (bran and other parts) and sugarcane bagasse have on the sensory and physical qualities of baked foods including cookies/biscuits, bread and cakes [23, 35–40]. This systematic review, therefore, endeavours firstly to review the role of dietary fibre derived from selected cereals (rice bran and corn fibre) and sugarcane bagasse in baked foods, namely cookies/biscuits, bread and cakes; secondly to evaluate the effects of the incorporation of dietary fibre derived from selected cereals (rice bran and corn fibre) and sugarcane bagasse on the physical and sensory qualities of these baked food products and finally to critically assess the beneficial impacts of dietary fibre incorporation derived from selected cereals (rice bran and corn fibre) and sugarcane bagasse in baked foods, including bread, cakes and cookies.

2. Methodology

The methodology follows applicable aspects of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [41] and includes details of the search strategy, studies selection, inclusion and extraction criteria, data extraction and assessment of study validity, risk of bias assessment and data analysis of the relevant studies utilised in this systematic review.

2.1 Research strategy

A systematic literature search using a Keyword-based concept was conducted for articles catalogued in ScienceDirect, Web of Science, PubMed, Medline, CINAHL and Google Scholar that were published between January 1, 2010 and August 1, 2020 using the following search strategy. The keyword-based searches included Boolean operators and were constructed using words from the research question along with the combination of truncations and wildcards to access as much primary research material as possible. The searches were limited to Scholarly and Peer-reviewed and English language. Grey areas of the literature such as government reports, conference reports and food magazines were also searched. Further, the reference lists of recent systematic reviews were searched for additional references.

2.2 Study selection, inclusion and exclusion criteria

The eligibility criteria utilised for the selection of relevant research studies followed the population, intervention, comparison, outcome and study settings (PICOS) research question framework. Further details are summarised in **Table 1**.

For studies to be included in the systematic review the following criteria were established, namely:

- The keywords and phrases e.g. arabinoxylans incorporation, rice and corn brans/fibre, sugarcane bagasse, baked food products among others relating to the research question should be included in the particular article title,

Population	Human subjects and quantitative parameters of nutritional and physical properties of baked foods including bread, cakes and cookies.
Intervention	Rice bran, corn fibre and sugarcane bagasse
Comparison	Nutrient profile, volume, texture, weight, height, colour and sensory evaluation metrics.
Outcome	Improve quality
Study Setting	All research studies investigating the effects of the incorporation of dietary fibres on the nutritional, physical and sensory qualities of baked food products.

Table 1.
PICOS criteria for study selection.

- Human subjects including adults/children,
- Food vehicles included bread, cakes and cookies,
- Source of arabinoxylans rice bran, corn bran and sugarcane bagasse,
- Quantity of arabinoxylans from the particular sources that was incorporated,
- Sensory evaluation,
- Quantitative parameters of nutritional profile e.g., fibre, fat, carbohydrates and protein content and physical profile e.g., texture, volume, weight, height and colour of baked foods including bread, cakes and cookies,
- Full text of articles (abstract only of articles would not be considered),
- Articles should be written in English language,
- The published dates of articles should be between January 1, 2010 and August 1, 2020,
- Controlling bias by using randomisation and mean measurements of food products from triplicates instead of a single measurement and
- Articles should be able to be placed into sub-groups to facilitate statistical analysis.

Studies under consideration for inclusion in the review which did not contain the required information as outlined previously were not selected. All articles chosen were sent to the EndNote reference database, which facilitated the identification of duplicate articles, which were also excluded from the review.

Articles consisted of a sensory evaluation of a particular baked food product, including bread, cakes and cookies; a nutritional and physical profiles of bread, cakes and cookies were deemed fundamental to the review since they provided data relating to the nutritional, physical and sensory qualities of baked foods being studied. The use of articles investigating the different dietary fibre sources of arabinoxylans (rice and corn brans and sugarcane bagasse) incorporation into foods facilitated the assessment of the effects of arabinoxylans incorporation into foods, its possible implications, roles and the possible optimum inclusion proportions of arabinoxylans, which may result in improved nutritional, physical and sensory qualities of different food products for consumer consumption. Priority was given to studies examining arabinoxylans derived from agricultural by-products of selected cereals (rice and corn) and sugarcane bagasse. Articles produced earlier than 2010 were excluded, mainly to reflect the recent advancement of public health policy guidelines, modern processing techniques and equipment within the food industry.

2.3 Data extraction and assessment of study validity

The data extracted from the studies were performed independently by the researcher and it included the pertinent characteristics of the studies relating to the research question of the systematic review. The characteristics used for the data extraction sheet consisted of the following headings:

- Authors' name
- Title
- Location of study and funding source
- The objective of the study
- Source of arabinoxylans and amount used
- Food vehicle (bread, cakes and cookies)
- Control of bias – Randomisation usage in design, triplicate measurements, statistical analysis and sensory evaluation
- Sensory evaluation metrics
- The nutrient profile of food product
- Physical parameters of food product (volume, texture, weight, height, colour)
- Statistical analysis
- Results
- Conclusion

The data from studies were checked for errors and any unavailable data was denoted as not determined (ND) in the particular table.

The assessment of study validity was conducted using the Downs and Black checklist [42]. This checklist is comprised of 27 questions and can be utilised in the assessment of the methodological quality of both randomised and non-randomised studies [42]. However, for this review only fourteen (14) questions were found to be applicable, the other questions were denoted as not applicable. The score ranges and corresponding quality levels used for the Downs and Black [42] were as follows: excellent (26–28); good (20–25); fair (15–19) and poor (≤14) [43]. Some of the included criteria relevant in the assessment of articles for this type of review comprised of the following areas:

i. Reporting

ii. External validity

iii. Bias

iv. Confounding factors

v. Statistical power

2.4 Risk of bias assessment

The risk of bias assessment of the articles used in this review was evaluated using the Cochrane collaboration's tool for assessing the risk of bias. The statistical information presented in the articles was assessed for its appropriateness. The outcomes reported in articles used were verified for accuracy and the section of the study it was first reported was noted. Moreover, the credentials and attachments of the respective authors of the articles utilised in the review were also checked. Importantly, references to the disclosure of interest were keenly examined at the end of the articles.

2.5 Data handling

In this review, only eleven (11) research articles out of fourteen (14) studies were considered suitable for statistical data analysis. There were five (5) studies that focused on rice bran as the arabinoxylan source and both cookies/biscuits (3 studies) and bread (2 studies) as the food vehicle; four (4) studies used corn fibre as the arabinoxylan source and both cakes (2 studies) and cookies/biscuits (2 studies) and finally two (2) studies conducted research using sugarcane bagasse as the arabinoxylan source and cookies/biscuits as the food vehicle. In the area of sensory evaluation, various scales were used in the assessment of particular sensory attributes such as hedonic scales (5-point, 7-point and 9-point) and10 cm unstructured line scale. Thus, sensory assessment scores were standardised by dividing individual scores given by the panel by the maxima of the particular scale used, then multiply by 100 to convert to a percentage. Data of panellists were extracted and grouped into categories of trained, semi-trained and untrained; gender and nationality and utilised to conduct a descriptive statistical analysis. Students were grouped as semi-trained and in studies that did not specify the training of panellists, they were classed as untrained. Studies were grouped into sub-groups according to the food vehicle and source of arabinoxylan that was incorporated into the food product. The weighted means of the papers was calculated by using the Statistical Package for Social Sciences (SPSS), version 26 software. Moreover, the percentage of fibre incorporation was also similar for each sub-group utilised for data analysis. The metrics extracted from the included studies relating to the physical analysis of the particular food vehicle were also standardised namely for bread: volume (ml), mass (g) and specific volume (g/ml); cookies/biscuits: width (mm), thickness (mm), spread factor (%) and colour: L*, a* and b* and finally cakes: crumb colour: L*, a* and b*, crust colour: L*, a* and b* and texture (Kg F).

2.6 Data outputs

The fundamental characteristics extracted from the articles were conducted using applicable aspects from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [41]. Statistical analysis of data extracted from the various studies included in the review was performed using a Simple (one-way) analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS), version 26. Post Hoc analysis was conducted using Tukey's test to identify where the difference lies between each group, (see Appendix F). The significant difference between the means was identified where ($p \le 0.05$).

3. Results

3.1 Study selection

In this systematic review, a total of fourteen (14) studies satisfied the inclusion criteria established, the process that guided the selection of these studies is illustrated in the PRISMA diagram (see **Figure 1**). However, only eleven (11) studies facilitated categorisation into a sub-group, namely bread, cakes and cookies/biscuits and then further sub-divided into fibre type and food vehicle and were thus considered suitable to be utilised for statistical analysis, (see **Table 2**). In the fourteen (14) studies included, all conducted a sensory evaluation study, a nutritional analysis/profile and a physical analysis of the particular food produced being studied, except the research studies completed by [17, 23], there was no nutritional analysis/profile and the study carried out by [44], which did not perform a physical analysis of the chapatti, a type of fermented bread. The sensory studies consisted of 362 participants from eleven (11) countries, see **Figure 2**. Panel members used in the

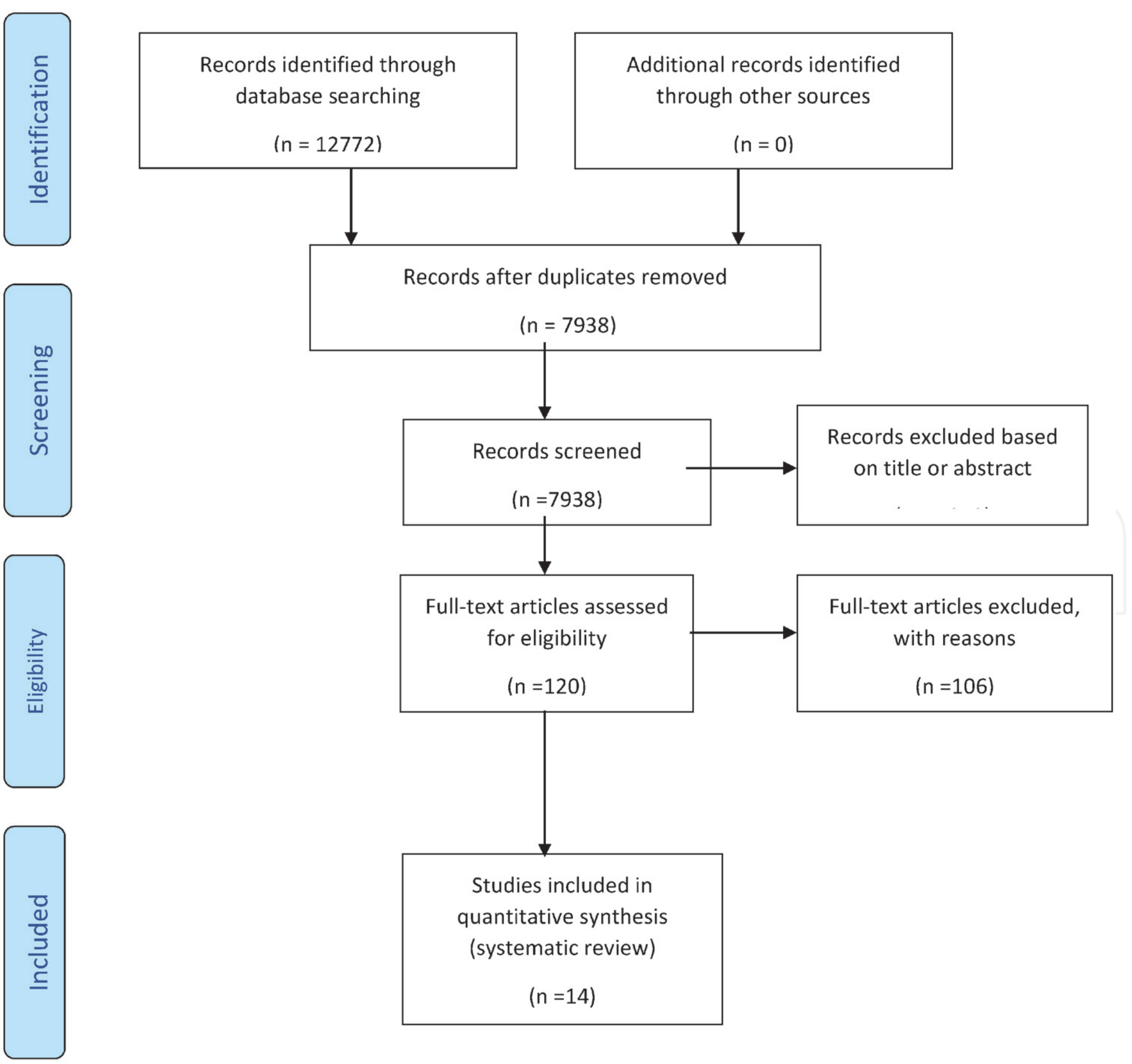

Figure 1.
Study selection process based on PRISMA guidelines. Adapted from [41].

Detail	Appearance	Taste	Texture	Overall acceptance
Control (0%)	85.6 ± 8.6a	86.9 ± 9.8c	86.2 ± 9.2a	86.1 ± 9.2a
5% SCB	84.2 ± 7.5b	82.1 ± 7.4b	82.1 ± 7.4b	84.2 ± 7.5a
10% SCB	68.9 ± 18.9c	69.5 ± 21.0c	72.3 ± 13.4c	72.3 ± 13.4b

Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: SCB – sugarcane bagasse.

Table 2.
Sensory quality of sugarcane bagasse enriched cookies/biscuits.

sensory studies ranged from 5 to 60 participants and the mode were 30 and 10 panellists. The panellists were grouped into trained, semi-trained and untrained, see **Table 2**. The panel members were also made up of both gender (male and female), age groups (which ranged from 18 to 50 years old) and occupations (staff members, post-graduate students and others not mentioned). In addition, eight (8) of the 14 studies were conducted in Asia, namely Sri Lanka - 1, India – 3, Iran – 1, Pakistan – 2 and Bangladesh – 1. Two (2) studies were conducted in North America, namely United States – 1 and Mexico – 1 and two (2) studies were carried out in Africa, namely Cameroon –1 and Nigeria - 1. Finally, one study was conducted in Brazil, South America. Studies examined various baked food products, namely bread - four (4) studies), cakes - three (3) studies, cookies/biscuits studies - seven (7) studies.

The metrics utilised in the sensory studies of this review encompassed colour of crumb and colour of crust; aroma; flavour; appearance; taste; texture firmness or hardness and overall acceptability, see **Table 2**. Meanwhile, for the physicochemical and physical characteristics aspects of the studies, the parameters examined included moisture %, protein %, ash %, fat %, carbohydrates %, crude fibre %,

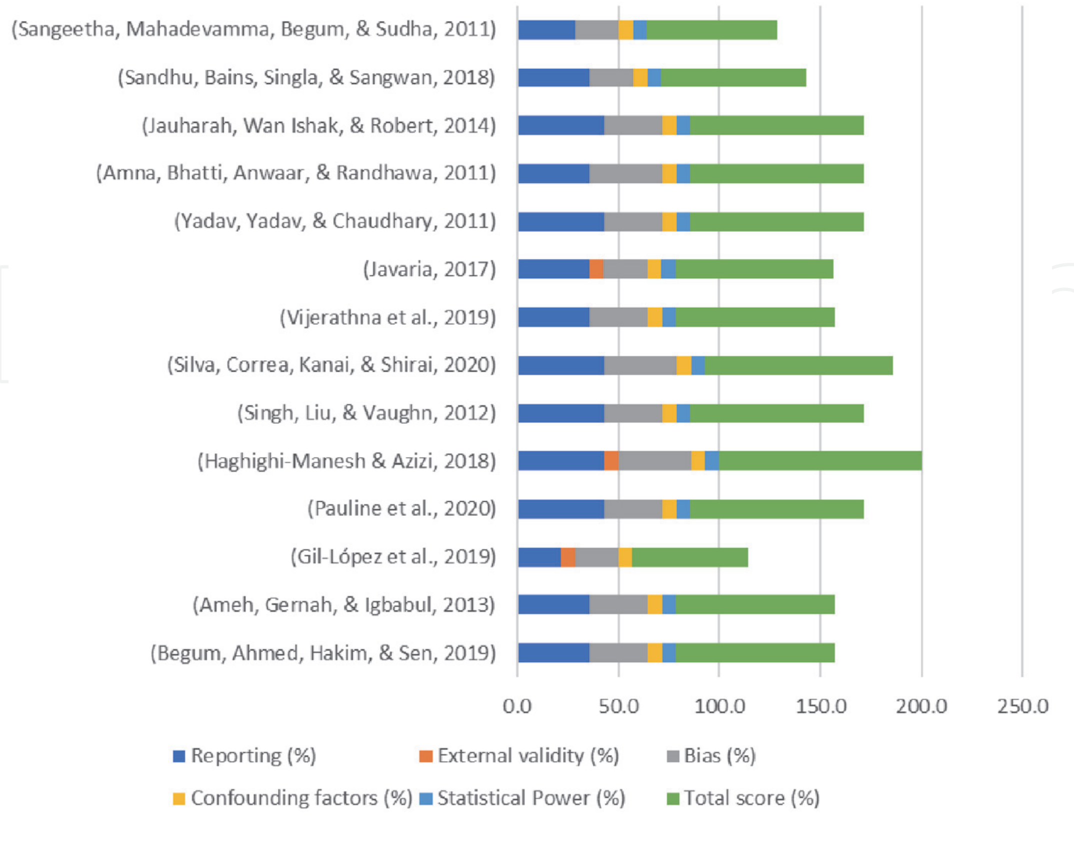

Figure 2.
Quality assessment results of the various studies used in the review, presented in percentages per category and overall total using the Downs and Black checklist.

mineral contents and phenolic contents; texture for example firmness or hardness; colour or luminosity of crust and crumb (for example lightness/brightness, redness/greenness and yellowness/blueness); loaf weight, bread height and bread volume; diameter, thickness, spread ratio and texture, see **Table 2**. The intervention data extracted were the various dietary fibres derived from arabinoxylans selected sources, namely rice bran, corn fibre and sugarcane bagasse and which was supplemented at different rates ranging from 0–30% into baked foods bread, cakes and cookies/biscuits.

3.2 Data quality

The quality assessment of the fourteen (14) research studies included in the review was conducted using the Downs and Black [42] checklists, importantly only fourteen (14) questions were considered applicable, the other questions were denoted as not applicable to this review and consequently were not utilised to assess the included studies. The highest score was received by the research paper [17], namely 14/14, while the lowest score was obtained by the research paper [44], namely 8/14. Five (5) research papers received 11/14; four (4) research papers received 12/14 and one (1) research paper each received scores of 13/14, 8/14, 9/14 and 10/14 respectively, (see **Figure 2**). Thirteen (13) out of the fourteen (14) studies excelled in the category of reporting, only [44] scored poorly. In the category of bias or internal validity all fourteen (14) papers received satisfactory scores, contrasting in the category of external validity only two (2) studies excelled, the other studies failed to show that the panel members were chosen from a representative sample. Moreover, in areas of confounding factors and statistical power, the majority of studies received high scores. Based on the scoring scale of the Downs and Black [42] checklists the quality of the fourteen (14) studies would be considered in the range of fair to excellent [43].

3.3 Data analyses

This section entails the review and analysis of the findings of the primary research articles included in the review which were categorised into sub-groups to reveal common effects and enhance statistical power, except for those papers which did not enable statistical analysis. The studies were grouped as follows: the types of food or food vehicle namely, cookies, biscuits, bread and cakes and fibre; the type of fibre supplemented into the food product, namely rice bran, corn fibre and sugarcane bagasse and the particular outcomes: effects or no effects were outlined or highlighted, (see **Table 2**). The included studies were further sub-divided into specific food and fibre types; the same rates of fibre incorporation into the particular food product as the food vehicle and their respective similar sensory metrics and physical parameters were extracted from the eleven (11) studies to facilitate statistical analysis. The findings will be presented under three (3) main food type headings, namely cookies/biscuits, bread and cakes to facilitate a logical presentation.

3.3.1 Cookies/biscuits: sugarcane enriched

The incorporation of sugarcane bagasse up to the level of 10% showed significantly undesirable overall acceptance ($p < 0.05$). Moreover, based on the sensory evaluation results, as the level of sugarcane bagasse increased, the overall acceptance of enriched cookies/biscuits reduced significantly ($p < 0.05$), see **Table 2**. Cookies/biscuits incorporated with sugarcane bagasse at 5% were similar to control.

Sugarcane bagasse incorporation up to 10% resulted in no significant differences ($p > 0.05$) in the physical quality of the cookies/biscuits. In **Table 3**, the thickness of fibre supplemented cookies was marginally less than the control sample and although the enriched cookies/biscuits were slightly wider, enrichment produced a reduction in the parameter of spread factor and was more 2 times harder than control cookies/biscuits.

3.3.2 Cookies/biscuits: rice bran enriched

Rice bran fibre supplemented cookies/biscuits up to 15% showed significantly undesirable overall acceptance. The sensory scores were all lower than the control sample according to sensory evaluation. Rice bran enriched samples obtained, namely 15% incorporation obtained the low scores for most of the sensory attributes assessed, see **Table 4**. Overall acceptance of cookies/biscuits significantly reduced ($p < 0.05$) in comparison to the control sample of cookies/biscuits. Incorporation of rice bran into cookies/biscuits at 10% performed only slightly better than 5% and 15% levels of incorporation. However, the control sample obtained the best overall acceptance based on sensory evaluation.

The incorporation of rice bran into cookies/biscuits significantly ($p < 0.05$) enhanced the thickness of the food product. The width and degree of spread factor showed no significant differences in comparison to the control. Further details are outlined in **Table 5**.

3.3.3 Cookies/biscuits: corn fibre enriched

Corn fibre supplemented cookies up to 20% obtained a significant ($P < 0.05$) desirable overall acceptance based on sensory panel evaluation. There were significant differences ($p < 0.05$) in colour between enriched corn fibre cookies/biscuits and the control. Interestingly, 20% supplemented obtained the best score for overall

Detail	Thickness (mm)	Width (mm)	Spread factor (SF%)	Texture (Kg force)
Control (0%)	5.3 ± 0.3a	48.9 ± 10.3b	100.0 ± 0.0c	5.7 ± 5.4d
5%	4.9 ± 0.2a	51.0 ± 6.6b	87.3 ± 3.0c	7.6 ± 6.6d
10%	4.9 ± 0.4a	51.9 ± 5.0b	83.4 ± 9.5c	13.0 ± 3.9d

Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: SCB – sugarcane bagasse.

Table 3.
Physical quality of sugarcane bagasse enriched cookies/biscuits.

Detail	Flavour	Colour	Taste	Texture	Overall acceptance
Control (0%)	79.8 ± 14.5a	80.5 ± 15.1a	76.5 ± 13.0a	72.9 ± 11.7a	78.4 ± 12.3a
5% RB	70.9 ± 10.8ab	73.3 ± 11.7ab	69.6 ± 14.2ab	67.3 ± 10.7b	72.1 ± 11.0b
10% RB	72.9 ± 8.5ab	72.4 ± 4.7ab	71.3 ± 7.1ab	71.4 ± 9.7a	72.3 ± 5.4b
15% RB	71.7 ± 5.2ab	71.4 ± 7.2ab	67.4 ± 8.0ab[1]	71.5 ± 1.0a	71.0 ± 3.1b

Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: RB – rice bran, ab[1] is significantly different from control and 10% RB samples.

Table 4.
Sensory quality of rice bran enriched cookies/biscuits.

Detail	Thickness (mm)	Width (mm)	Spread factor (SF%)
Control (0%)	8.6 ± 1.0a	42.7 ± 13.6b	51.7 ± 5.2c
5% RB	9.5 ± 0.5ab[1]	40.5 ± 13.2b	49.4 ± 5.6c
10% RB	9.6 ± 0.1ab	38.8 ± 12.9b	46.5 ± 6.6c
15% RB	9.9 ± 0.3ab	36.9 ± 13.8b	44.5 ± 6.9c

Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: RB – rice bran and ab[1] – no significant difference between 5% and 10% RB supplementation.

Table 5.
Physical quality of rice bran enriched cookies/biscuits.

Detail	Flavour	Colour	Appearance	Texture	Overall acceptance
Control (0%)	81.5 ± 10.4a	81.2 ± 10.9a	83.2 ± 10.9a	85.3 ± 6.3a	83.2 ± 10.9a
10% CF	83.8 ± 7.9a	82.6 ± 10.4ab	83.2 ± 10.9a	85.3 ± 6.3a	84.4 ± 8.4ab
20% CF	79.9 ± 13.4ab	79.3 ± 12.8ab	79.9 ± 13.4a	80.8 ± 13.6b	86.7 ± 5.3ab
30% CF	67.8 ± 14.5b	70.0 ± 19.8 ac	67.2 ± 17.7b	67.9 ± 18.2c	67.2 ± 17.7c

Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: CF – corn fibre.

Table 6.
Sensory quality of corn fibre enriched cookies/biscuits.

acceptance. Moreover, both 10% and 20% enriched cookies/biscuits were found to be statistically similar, see **Table 6**.

In **Figure 3**, both 10% and 20% enriched cookies/biscuits obtained the best scores from panellists. Meanwhile, the incorporation of cookies/biscuits at 30% was not well accepted during sensory evaluation.

The physical qualities of up to 30% corn fibre supplemented cookies/biscuits were statistically similar to the control sample. However, cookies/biscuits incorporated with corn fibre up to 20%, showed increased thickness in comparison to the

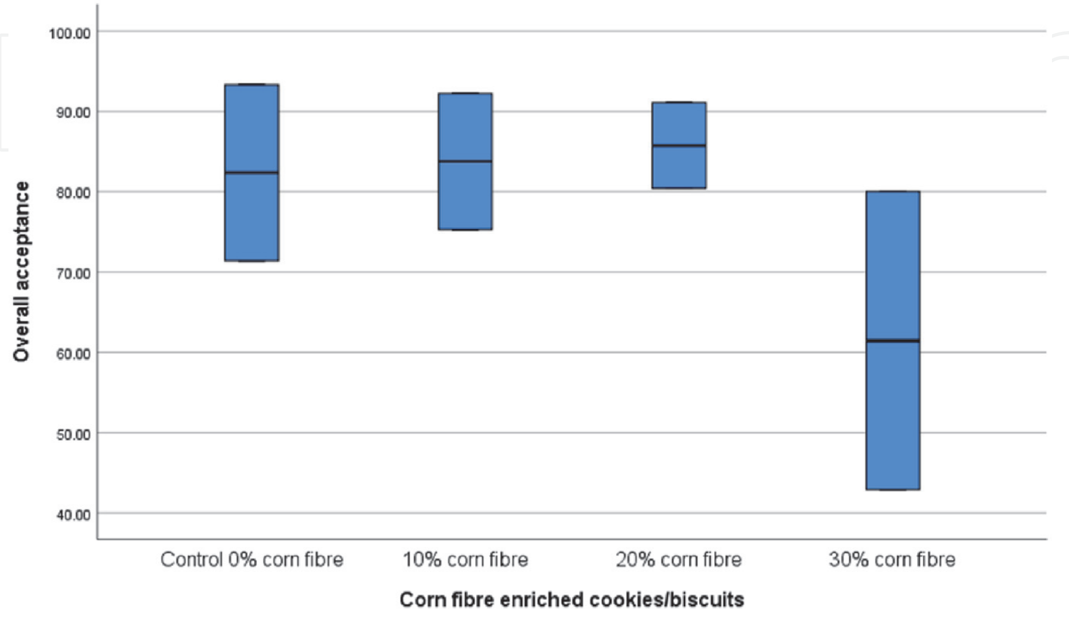

Figure 3.
Graph depicting overall acceptance of corn enriched cookies/biscuits.

Detail	Thickness (mm)	Width (mm)	Spread factor (SF%)	Texture (Kg force)
Control (0%)	5.9 ± 0.4a	49.1 ± 24.5b	76.9 ± 32.7c	1.6 ± 0.7d
10% CF	5.9 ± 0.4a	48.3 ± 19.9b	75.5 ± 25.6c	1.8 ± 0.5d
20% CF	6.1 ± 0.4a	48.4 ± 18.8b	74.0 ± 23.6c	1.9 ± 0.4d
30% CF	5.9 ± 0.7a	51.9 ± 5.0b	75.6 ± 19.5c	2.1 ± 0.2d

Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: CF – corn fibre.

Table 7.
Physical quality of corn fibre enriched cookies/biscuits.

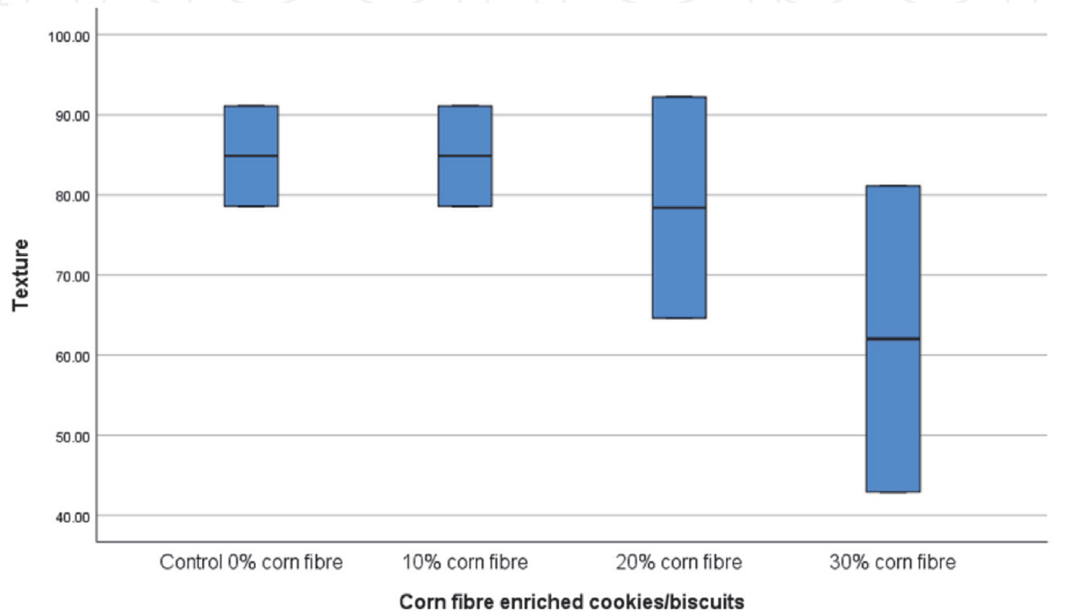

Figure 4.
Graph depicting the sensory attribute – the texture of corn fibre incorporated cookies/biscuits.

control sample, see **Table 7**. Incorporation of corn fibre at 30% gave cookies/biscuits the highest firmness 2.1 ± 0.2 (Kg Force).

In **Figure 4**, the texture of corn fibre enriched cookies/biscuits incrementally reduced with the incorporation of increased fibre up to 30%.

3.3.4 Rice bran enriched bread

In **Table 8**, incorporation of rice bran into up to 15% produced significantly ($p < 0.05$) undesirable overall acceptance. There was a significant difference ($p < 0.05$) in the aroma of the fibre enriched bread and control bread. All the rice bran fibre enriched bread was similar to each other but all significantly different ($p < 0.05$) from the control. There was no significant difference in the overall acceptance of 5% and 10% rice bran incorporated bread from the control sample.

In **Table 9**, there were no significant differences between rice bran supplemented bread up to 10%.

3.3.5 Sensory quality of corn bran enriched cakes

Based on sensory evaluation corn bran supplemented cakes up to 20% were found to be significantly desirable ($p < 0.05$) in comparison to control cake samples

Detail	Aroma	Crust colour	Crumb colour	Taste	Texture	Overall acceptance
Control (0%)	86.1 ± 3.9a	90.5 ± 2.4a	87.2 ± 3.9a	83.3 ± 1.6a	88.4 ± 0.8a	88.4 ± 0.8a
5% RB	73.9 ± 3.2ab	80.0 ± 7.7a	77.8 ± 6.4a	78.4 ± 3.2a	79.4 ± 5.8a	80.6 ± 0.6a
10% RB	71.1 ± 8.5ab	71.7 ± 11.6a	72.2 ± 8.5a	75.0 ± 6.7a	80.8 ± 13.6a	72.8 ± 10.4a
15% RB	68.9 ± 7.2ab	71.7 ± 11.3a	68.3 ± 6.5a*	68.9 ± 5.3a*	80.8 ± 8.3a*	68.4 ± 7.8a*

*Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different (p < 0.05). Key: RB – rice bran and * means 15% is significant in comparison to control only.*

Table 8.
Sensory quality of rice bran enriched bread.

Detail	Specific volume (ml/g)
Control (0%)	10.7 ± 9.1a
5% RB	10.1 ± 6.9a
10% RB	9.8 ± 6.6a

Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different (p < 0.05). Key: RB – rice bran.

Table 9.
Physical quality of rice bran enriched bread.

Detail	Crust colour	Taste	Texture	Overall acceptance
Control (0%)	87.6 ± 6.3a	81.2 ± 10.9a	85.3 ± 6.3a	83.2 ± 10.9a
10% CB	86.1 ± 2.3a	82.6 ± 10.4ab	85.3 ± 6.3a	84.4 ± 8.4ab
20% CB	80.6 ± 0.6b	79.3 ± 12.8ab	80.8 ± 13.6b	86.7 ± 5.3ab

Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different (p < 0.05). Key: CB – corn bran.

Table 10.
Sensory quality of corn bran enriched cakes.

for the attributes of crust colour, taste, texture and consequently obtained the overall acceptance, see **Table 10**.

3.3.6 Physical quality of corn bran enriched cakes

Corn bran incorporated cakes significantly ($p < 0.05$) impacted the crust luminosity of cakes at both 25% and 30% supplementation levels. All the other physical parameters were similar to the control sample. The texture, namely firmness increased as the level of corn bran increased in the cakes, see **Table 11**.

Initially, the texture of corn bran enriched cakes increased with the addition of corn bran, then reduced at 10% level of incorporation and thereafter incrementally increased as the supplementation levels were elevated in cakes. Not surprisingly, the highest degree of firmness in cakes is at the 30% level of corn bran incorporation in cakes, see **Figure 5**.

Detail	Crust L*	Crust a*	Crust b*	Crumb L*	Crumb a*	Crumb b*	Texture (Kg Force)
Control (0%)	84.4 ± 4.2a	−3.9 ± 6.9a	28.6 ± 11.6a	51.1 ± 17.9a	11.7 ± 3.7a	34.5 ± 14.2a	6.7 ± 1.5a
5% CB	80.8 ± 2.9a	−3.6 ± 6.6a	31.7 ± 6.4a	50.7 ± 15.3a	11.1 ± 3.2a	35.2 ± 11.7a	6.9 ± 1.2a
10% CB	78.1 ± 1.4a	−5.1 ± 6.2a	31.8 ± 7.6a	48.8 ± 17.5a	10.3 ± 2.6a	36.1 ± 9.8a	6.9 ± 0.9a
15% CB	73.9 ± 3.6a	−5.0 ± 6.6a	33.2 ± 6.5a	47.1 ± 16.8a	9.8 ± 4.1a	36.3 ± 9.2a	7.1 ± 1.1a
20% CB	71.9 ± 3.5a	−5.4 ± 7.5a	34.6 ± 5.6a	46.9 ± 17.7a	8.0 ± 3.8a	36.9 ± 7.4a	7.4 ± 1.2a
25% CB	68.2 ± 6.7b	−5.8 ± 8.5a	35.5 ± 5.2a	46.5 ± 18.4a	6.8 ± 4.6a	37.5 ± 6.6a	7.7 ± 1.2a
30% CB	64.7 ± 7.0b	36.6 ± 5.0a	36.6 ± 5.0a	45.7 ± 19.3a	5.4 ± 4.4a	37.5 ± 4.9a	7.7 ± 1.1a

Values are means ± standard deviation of sub-groups. Means in the same column with different superscripts are significantly different ($p < 0.05$). Key: CB – corn bran.

Table 11.
Physical quality of corn bran enriched cakes.

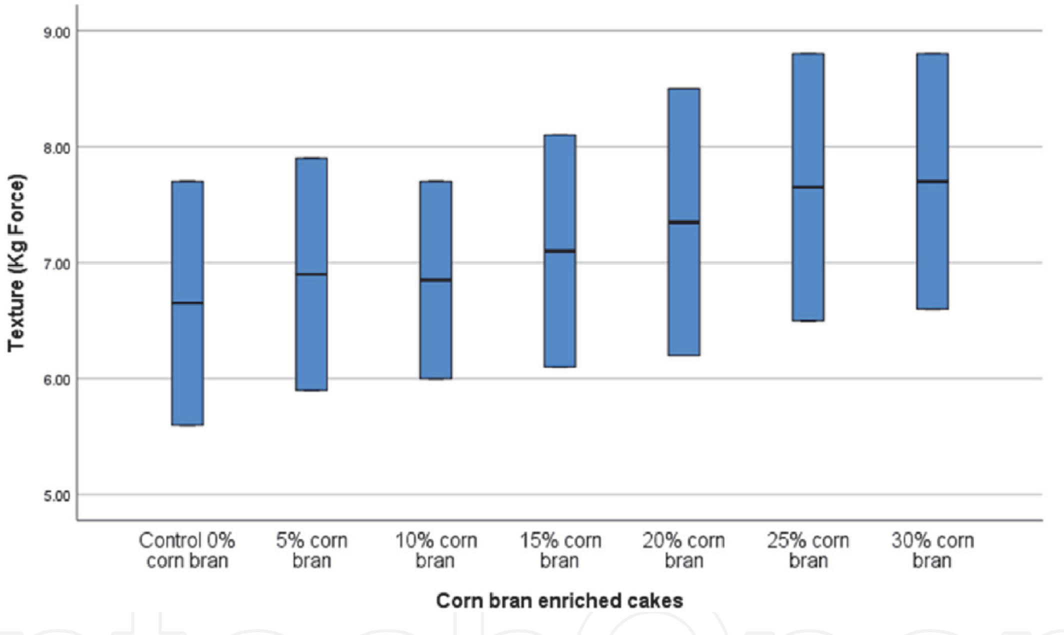

Figure 5.
Graph depicting the texture qualities of corn bran enriched cakes.

3.4 Data Characteristics and features

Several baked food products, namely cookies/biscuits, cakes and bread illustrated enhanced levels of dietary fibre, moisture, ash, minerals, vitamins contents and on the other hand reduction in proteins, fats and carbohydrates, see **Table 12**. The incorporation of rice bran up to the level of 15% into biscuits significantly ($p < 0.05$) enhanced its nutritional value [20]. In previous studies Yadav, Yadav, and Chaudhary [39] also found that the supplementation of biscuits up to 15% significantly ($p < 0.05$) enhanced its nutritional value in comparison to the control sample, namely significant increase in protein content from 7.3% to 15.4%; there was a non-significant increase in ash and fibre contents and a reduction in carbohydrates content. Several studies of cookies and biscuits using both higher rates of corn fibre (up to 40%) and rice bran (up to 20%) also reported a significant

Reference	Downs and Black quality assessment	Food vehicle	Fibre type and % incorporation	Control	n	Analysis parameters	Panel[a]	Outcomes
[45]	11/14	Cookies	Rice bran – acid stabilised and heat stabilised (0–20%)	Wheat flour	5	Physical parameters: • Width (mm) • Thickness (mm) • Spread factor (%) • Texture (Kg F) Sensory attributes: flavour, colour, appearance, taste, texture and overall acceptability.	Postgraduate students – Food Technology Department (T)	• No significant difference was detected in the chemical and physical properties of cookies incorporated with acid stabilised rice bran (ASRB) and heat stabilised rice bran (HSRB). • The incorporation of brans in cookies resulted in a significant incremental increase of moisture, crude protein, fat and mineral contents. • The parameters of average width, thickness and spread factor of cookies were also increased as rice brans were added. • The scores for colour of cookies decreased significantly as the level of rice bran increased, but not was non-significant at the 10 percent level of substitution.
[20]	11/14	Biscuits	Rice bran (0–10%)	Wheat flour	26	Physical parameters: • Width (mm) • Thickness (mm) • Spread factor (%) • Texture (Kg F) Sensory attributes: flavour, colour, appearance, taste, texture and overall acceptability.	Males and females (50% males and 50% females), age ranged 20–50 years, untrained panellists (UT)	• Biscuits supplemented with 5–10% heat stabilised rice bran using flour containing (rice flour 35% + maize flour 35% + pea flour 30%) resulted in desirable overall acceptance by the sensory panel. • Incremental addition of stabilised rice bran significantly increased moisture, ash, crude protein, fibre and thickness of the biscuits. • Width and spread factor of biscuits reduced with increasing levels of stabilised rice bran.
[39]	12/14	Biscuit	Rice bran protein concentrate	Refined wheat flour	10	Physical parameters: • Width (mm) • Thickness (mm) • Spread factor (%)	Semi-trained members (ST)	• The substitution of refined wheat flours up to 10 per cent using RBPC resulted in the formulation of protein-enriched biscuits with favourable overall acceptability.

Reference	Downs and Black quality assessment	Food vehicle	Fibre type and % incorporation	Control	n	Analysis parameters	Panel[a]	Outcomes
			(RBPC) (0–15%)			• Texture (Kg F) Sensory attributes: flavour, colour, appearance, taste, texture and overall acceptability.		• There was a significant increase in the protein content of biscuits produced from 7.3% in control biscuits to 15.4% in the biscuits with 15% rice bran supplementation. • The fracture strength was also significantly higher than that of the control biscuits ($p < 0.05$).
[46]	12/14	Biscuits	Corn fibre (0–30%)	Wheat flour	60	• Texture • Diameter (W):mm • Thickness (T): mm • Spread ratio • % spread factor • Sensory attributes of appearance, colour, texture, taste, flavour and overall acceptability.	Untrained panellists	• Significant enhancement of protein and dietary fibre contents of the cookies. • Hardness of the cookies also increased as the level of dried young corn increased in the cookies. • Supplementation of cookies with 10% dietary obtained the best scores in comparison to the control.
[36]	10/14	Biscuits	Corn fibre (10–40%)	Refined wheat flour	10	• Texture • Diameter (W):mm • Thickness (T): mm • Spread ratio • % spread factor • Sensory attributes of appearance, colour, texture, taste, flavour and overall acceptability.	Semi-trained panellists (ST)	• Corn fibre replacement in refined wheat flour resulted in enhanced hardness, thickness, moisture, total dietary fibre (TDF) and moisture in biscuits and simultaneously a significant reduction in carbohydrates and energy. • Reduced diameter was observed and a reduced spread ratio was derived. • Sensory evaluation results of the attributes of colour, appearance, texture, taste, flavour and overall acceptability of biscuits were similar to the control up to the level of 20% addition of corn fibre.

DOI: http://dx.doi.org/10.5772/intechopen.99488

Reference	Downs and Black quality assessment	Food vehicle	Fibre type and % incorporation	Control	n	Analysis parameters	Panel[a]	Outcomes
[38]	11/14	Cookies	Sugarcane bagasse – with peel (0–10%)	Wheat flour	30	Physical parameters: • Width (mm) • Thickness (mm) • Spread factor (%) • Colour: L*, a* and b* • Texture (Kg F) Sensory attributes: colour, appearance, taste, texture and overall acceptability.	Trained panel members (T)	• The incorporation of sugarcane bagasse with a peel at 5% to enrich cookies displayed the highest overall acceptability. • Enriched cookies with 5% peeled sugarcane contained increased phenolic content, moisture content, fat and ash content, but slightly lower protein content in comparison to the control. • 5% enriched sugarcane bagasse (with peel) possessed a golden-brown colour, along with increased hardness, diameter and spread ratio but reduced thickness in comparison to the control cookies. Both cookies were of similar weight.
[37]	9/14	Biscuits	Sugarcane bagasse (0–15%)	Wheat flour	6	Physical parameters: • Width (mm) • Thickness (mm) • Spread factor (%) • Colour: L*, a* and b* • Texture (Kg F) Sensory attributes: colour, appearance, taste, texture and overall acceptability.	Panel members (UT)	• Biscuits with the incorporation of 10% steamed sugarcane bagasse and additives were highly acceptable based on the results of sensory evaluation. • Hardness and moisture of fibre enriched biscuits increased as the percentage of fibre added increased, contrastingly the surface features decreased. At 10% level of addition with additives, the texture of biscuits was enhanced and surface features improved. • The colour of the crumb at 10% fibre addition with additives was similar to the control – pale to yellow-brown, also its spread value and width increased, but thickness decreased.

Reference	Downs and Black quality assessment	Food vehicle	Fibre type and % incorporation	Control	n	Analysis parameters	Panel[a]	Outcomes
								• Dietary fibre content increased in fibre enriched biscuits but protein and fat contents were reduced in comparison to the control. • Micro-bacterial load of bagasse was reduced through the steaming process, and rheological features such as dough development, stability and viscosity were all negatively affected with increasing levels of fibre addition above 10%.
[47]	11/14	Bread	Full fatted rice bran (0–15%)	Wheat flour	20	Physical parameters: • Volume (ml) • Mass (g) • Specific volume (g/ml) Sensory attributes: aroma, crust colour, crumb colour, taste firmness, taste and overall acceptability.	Staff members and students (T)	• There were significant percentage increases in the nutrient contents of the rice bran supplemented bread, most notably the increase in protein, crude fat, carbohydrates, moisture, minerals and vitamins. • Importantly, there was a reduction in the sodium content of the bread samples. • As the level of rice bran incorporation increased in the bread samples from 5–15% it resulted in enhanced bread weight. • Contrastingly, both the volume and specific volumes of the bread samples were reduced. • There were significant differences illustrated between the physical properties of the control bread samples and the fibre incorporated bread samples: in both cases of dough and bread loaves.

Reference	Downs and Black quality assessment	Food vehicle	Fibre type and % incorporation	Control	n	Analysis parameters	Panel[a]	Outcomes
[31]	11/14	Bread	Full fatted & defatted rice bran (0–15%)	Wheat flour	10	Physical parameters: • Volume (ml) • Mass (g) • Specific volume (g/ml) Sensory attributes: aroma, crust colour, crumb colour, taste firmness, taste and overall acceptability.	Staff members and students (T)	• The hardness of composite bread increased with elevated supplementation of rice bran in flour. • The specific volume of the composite bread reduced with the addition of rice bran from 5–15%. • Rice bran incorporation in wheat flour enhanced the protein and crude fibre in comparison to the control wheat flour bread. • Supplementation of wheat flour with 10% of full fatted and defatted rice bran in the preparation of composite bread was found to be desirable overall • acceptability when compared to the control composite bread.
[48]	12/14	Bread	Maize bran (0%&30%)	Wheat flour	30	Physical parameters: • Volume (ml) • Mass (g) • Specific volume (g/ml) • Colour: L*, a* and b* Sensory attributes: flavour, crust colour, crumb colour, colour, taste, texture, and overall acceptability.	Untrained tasters (UT)	• The incorporation of brans in bread formula resulted in reduced bread volumes, and enhanced water, ash, lipids, proteins, fibres and phytates contents. • Maize bran supplemented bread recorded the highest phytate value (0.53 g/100 g DM) although lower than the control (2.5 g/100 g DM). • The addition of maize significantly ($p < 0.05$) enhanced mineral contents such as magnesium, potassium, zinc, manganese and iron in comparison to the control bread but had no significant effect on calcium and copper contents.

Reference	Downs and Black quality assessment	Food vehicle	Fibre type and % incorporation	Control	n	Analysis parameters	Panel[a]	Outcomes
[44]	8/14	Bread (chapatti/ fermented brad)	Sugarcane bagasse (0, 5 & 8%)	Wheat flour	50	Physical parameters: ND Sensory attributes: flavour, aroma, crust colour, and texture. Overall acceptability: ND	Students, between the ages of 18 and 36 years old (ST)	• Hedonic responses suggested that the addition of 8 wt.% of treated fibres during the production of chapatti-type fermented bread (with SCB) is suitable for human consumption. • Incorporation of food with sugarcane bagasse enhanced its nutritional value. • Increased in total fibre 7.4 ± 0.5–11.7 ± 0.6 g/100 g. • Similarity in the inhibition activity of the 2–2 diphenyl-1 picrylhydrazyl (DPPH) free radical values between control and sugarcane bagasse enriched bread. • Lower levels of crude fat, protein and ash content in sugarcane bagasse enriched chapatti bread in comparison to control samples and the other sugarcane tops enriched samples.
[17]	14/14	Cake	Corn bran (0–30%)	Cake formulation containing 0% corn bran	30	Physical parameters: • Crumb colour: L*, a* and b* • Crust colour: • L*, a* and b* • Texture (Kg F) Sensory attributes: flavour, crust colour, crumb colour, taste and overall acceptability.	Trained taste panellists (T)	• The inclusion of 5–10% modified corn bran in the cake formulation gave rise to the production of a functional cake. Above 10% fibre addition resulted in increased firmness and gumminess, but reduced springiness and cohesiveness. The colour of cakes significantly ($p < 0.5$) increased as corn bran incorporation levels rise above 5%. • Best acceptability of corn bran was at 5% followed by 10% supplementation levels. • 30% incorporation of corn bran obtained the lowest acceptability.

DOI: http://dx.doi.org/10.5772/intechopen.99488

Reference	Downs and Black quality assessment	Food vehicle	Fibre type and % incorporation	Control	n	Analysis parameters	Panel[a]	Outcomes
[49]	13/14	Banana cakes	Sugarcane bagasse (0–6%)	Oat flour	50	Physical parameters: • Crumb colour: L*, a* and b* • Crust colour: • L*, a* and b* • Texture (Kg F) Sensory attributes: crust colour, taste and overall acceptability.	Untrained panel members: mixture of staff and students (UT)	• The addition of sugarcane bagasse resulted in no distinct alteration in the chemical composition of the cakes. • Increased dietary fibre incorporation levels in cake resulted in increased firmness of the cake. • There was no interference in the sensorial acceptance of the product when dietary fibre was added between 3 and 6%. • Cakes with 6% sugarcane bagasse incorporation were considered acceptable and resulted in the preparation of desirable high fibre cakes.
[23]	12/14	Cakes	Corn bran (0–30%)	Cake flour	25	Physical parameters: • Crumb colour: L*, a* and b* • Crust colour: • L*, a* and b* • Texture (Kg F) Sensory attributes: flavour, crust colour, crumb colour, taste and overall acceptability.	Untrained panellists (UT)	• The increasing levels of corn bran replacement in cake batter showed no influence on the hardness and springiness of cakes. • Substitution of flour with 20% corn bran resulted in cakes with favourable sensory scores in the attributes of texture, taste and overall acceptability of the cakes.

[a]*Description is given by author. Trained (T), semi-trained (ST) and untrained (UT).*

Table 12.
General study features and characteristics of cookies/biscuits, bread and cakes.

increase in protein, fibre, minerals and moisture contents, on the contrary, fat contents and total carbohydrates showed a reduction in cookies and biscuits [45, 46].

In another study, protein contents in corn fibre enriched biscuits showed a reduction, as reported in most other studies ash, moisture and total dietary fibre contents were higher than in control biscuits [36]. Jauharah, Wan Ishak, and Robert [46] indicated that supplementation of biscuits with corn fibre up to 30% resulted in enhanced energy value. Contrastingly, more recently Sandhu, Bains, Singla, and Sangwan [36] revealed that biscuits supplemented with corn fibre up to 40% produced enriched biscuits with reduced energy value in comparison to control (a reduction from 499 Kcal to 486 Kcal). Moreover, there was evidence of reduced carbohydrates contents in corn fibre incorporated biscuits [36]. A recent study of sugarcane bagasse incorporation of cookies up to 10% Vijerathna et al. [38] indicated the presence of enhanced phenolic content and significantly higher ash and moisture contents, marginally similar fat composition in control and enriched cookies, but protein contents in enriched cookies were significantly lower than in the control sample. In 2011, Sangeetha, Mahadevamma, Begum, and Sudha indicated that sugarcane bagasse supplemented biscuits up to 15% biscuits possessed reduced total fat and protein contents, meanwhile, there were minimal variances in moisture content, ash and acid-insoluble contents in comparison to control.

There were two (2) studies, namely [17, 23] relating to corn bran supplemented cakes using similar incorporation percentages, namely 0–30% and that did not conduct any nutritional analysis, hence no data nutritional data were extracted from these studies. Rice bran supplemented bread up to 15% resulted in a significant (0.05) increase in moisture, protein, crude fibre, crude fat, ash and several minerals and vitamins in comparison to control bread [31, 47]. Importantly, it was reported in a study of enriched bread with rice bran that the sodium content was significantly (0.05) reduced, the composition of carbohydrates was reduced in enriched bread [47]. Further, a significant increase ($p < 0.05$) was reported in ash, moisture, proteins, lipids and minerals for example magnesium, potassium, zinc, manganese and iron; carbohydrates and energy value (Kcal/100 g) was significantly reduced ($p < 0.05$) and interestingly phytic acid contents of enriched bread using maize bran at 30% supplementation [48]. More recently, Gil-López et al. [44] stated that supplementation of chapatti using sugarcane bagasse resulted in enhanced total fibre 7.4 ± 0.5–11.7 ± 0.6 g/100 g, promote inhibition activity of the 2–2 diphenyl-1 picrylhydrazyl (DPPH) and also reduced the levels of crude fat, protein and ash content in enriched bread in comparison to control samples.

4. Discussion

4.1 Roles of dietary fibre in foods

4.1.1 Fortification of foods

Dietary arabinoxylan-based sources namely, rice bran, corn, and sugarcane bagasse can be used to improve the nutritional contents of baked foods and making them become functional products. In recent studies, Haghighi-Manesh & Azizi [17] reported that the inclusion of 5–10% modified corn bran in the cake formulation gave rise to the production of a functional cake with reduced cohesiveness and springiness higher gumminess, darkness, and favourable sensory properties. This suggests that corn bran can be added to baked food products to enhance nutritive value, textural qualities and sensory qualities. Moreover, incorporation of food with sugarcane bagasse at 8% supplementation and other dietary fibre arabinoxylan sources into food systems such as bread tend to enhance its nutritional value and influence changes in the physical, rheological, and sensorial characteristics of foods [24, 44]. Also, previously, Amna, Bhatti, Anwaar, & Randhawa [45] indicated that enhance moisture, protein, fat and minerals (calcium, manganese, and magnesium) composition in cookies was reported as the level of rice bran incorporation increase in biscuits. The evidence suggests that 20% fibre incorporated rice bran cookies may possess a significant increase in moisture, protein and minerals (zinc and Iron) contents. Meanwhile, in bread, Pauline et al., [48] indicated a significant increase ($p < 0.05$) in water, ash, lipids, proteins, fibres and phytic acid contents between the control sample and enriched maize bran bread. The incorporation of 8.2 g of AXE per 100 g of available carbohydrates into bread facilitated the criteria for the health claim of the reduction of post-prandial glycaemic response [7, 50]. This suggests that enrichment using arabinoxylans-based sources can improve the nutritive value of ordinary food products.

4.1.2 Water retention capacity

Arabinoxylans dietary fibre sources tend to affect the moisture content of foods positively. Several studies reported the increase of moisture content in the enrichment of cookies/biscuits, bread and cakes, in comparison to the control samples, in some cases moisture was increased significantly ($p < 0.005$) and other cases marginally [31, 36, 38, 48, 49]. Javaria [20] indicated that moisture content in cookies/biscuits can consider a fundamental quality since it tends to influence both end quality and shelf life of these food products. Arabinoxylan based sources during addition to dough tend to enhance viscosity and water absorption; improved dough development, reduce starch retrogradation and reduce the firmness of foods due to the presence of bound water facilitating less stiff gluten and starch network [22, 51]. This suggests that arabinoxylan dietary fibres supplementation into foods can enhance its moisture content and affect other properties in foods namely its storage properties and shelf life. However, in bread, it was proven that arabinoxylan has a beneficial effect on water activity and thus favourably influenced bread freshness [22]. Moreover, Jauharah, Wan Ishak, & Robert [46] stated that moisture in the range of 1–5% is considered a benchmark for cookies/biscuits and that fresh corn fibre may lead to too high moisture levels in foods and consequently result in food spoilage. It can be suggested that excess moisture may result in micro-bacterial activities which can impact shelf life unfavourably. Similarly, in the enrichment of bread with 20% corn bran high, bread quality was significantly affected by the water content in the composite formula [52]. Taken together, water retention capacity is fundamental in influencing baked foods' end quality.

4.1.3 Dietary fibre enriched food qualities and functional food ingredients

Arabinoxylans sources, namely rice bran, corn fibre and sugarcane bagasse tend to influence various qualities of enriched foods. Arabinoxylans (AXE) contribute essentially in determining the physical and chemical properties of the final quality of food products and made up a high percentage of the cell walls of cereal grains and also present in sugarcane bagasse [16, 22, 53]. In earlier studies, Foschia, Peressini, Sensidoni, and Brennan [13] indicated also that the quality and nutritional aspects of cereal products are influenced by the addition of dietary fibres into foods. Importantly, rheological properties among arabinoxylan fibres such as corn fibres displayed differences that may influence the quality of food products after their incorporation during food processing [54]. It can be hypothesised that rheological factors can contribute to some of the undesirable features in dietary fibre enrichment of baked foods. Numerous studies have conducted dietary fibre supplementation of cookies/biscuits, bread and cakes using rice bran, corn fibre and sugarcane bagasse at different rates of incorporation and with varying results, see **Table 12** [17, 23, 38, 39, 47]. This suggests that fibre incorporation using rice bran, corn fibre and sugarcane bagasse tend to produce both desirable and undesirable physical and sensorial features in baked food products.

Moreover, because of the favourable nutritive value impact of dietary fibres on enriched foods, and the health-related benefits that be obtained upon consumption in a prescribed manner, it can be suggested that these ingredients can potentially be considered as functional ingredients in baked foods. In support of the suggestion, Zidan and Eldemery [55] found that the incorporation of 5–10% defatted black rice bran was found to possess acceptable sensory features and resulting in the nutritive value of bread being enhanced with minerals such as phosphorus, potassium, iron, copper, zinc and calcium. Contrastingly, Zhang et al. [40] found that arabinoxylan fortification of bread with 10% arabinoxylan fibre illustrated undesirable physical qualities in bread such as decreased specific volume, harder crumb, darker crust colour, and a coarser crumb structure. Overall dietary fibres facilitate the production of enriched foods, which may possess both desirable and undesirable sensorial and physical qualities, which can be attributed to the rheological behaviour of dietary fibre arabinoxylan when used in food supplementation.

4.2 Effects of the incorporation of dietary fibre derived from selected cereals (rice bran and corn fibre) and sugarcane bagasse on the physical and sensory qualities of baked food products: cookies/biscuits, bread and cakes

The incorporation of sugarcane bagasse at both 5% and 10% in cookies/biscuits resulted in significantly undesirable ($p < 0.05$) overall acceptance in sensory qualities, namely appearance, taste and texture, (see **Table 2**). It can be suggested that the increased firmness of the cookies/biscuits increased as the rate of supplementation of sugarcane bagasse increased affected its overall acceptance negatively, (see **Table 3**). Javaria [20] indicated that the firmness in cookies tends to influence their overall acceptance by the panellists. Sugarcane bagasse incorporation in cookies / biscuits showed no significant improvement in the physical qualities of the enriched product in comparison to the control. This can be attributed to the rheological properties of dietary arabinoxylans within the food matrix of the enriched biscuits. Kale, Pai, Hamaker, and Campanella [54] found that the rheological properties of extensional viscosity and solution viscosity of arabinoxylans fibres in the food system tend to influence its quality. This suggests that as the competition may have increased between the dietary fibre and the protein network, it resulted in a re-arrangement of the food matrix network. The incremental addition of sugarcane bagasse resulted in at least 50% rise in the firmness of 10% enriched cookies/biscuits. This can be attributed to the stiffness of the gluten and starch matrix may have been destroyed due to the competition of unextracted arabinoxylan dietary fibre and proteins for bound water. In a previous study of biscuits, Sozer, Cicerelli, Heiniö, and Poutanen [56] found that the hardness of biscuits was increased due to the particle size reduction of bran, while the starch hydrolysis index of biscuits decreased due to particle size reduction of bran.

In rice bran enriched cookies/biscuits incorporation levels of 5–15% showed a significant difference in comparison to control cookies/biscuits. Interestingly, a low fibre incorporation of rice bran of 5% displayed significantly ($p < 0.05$) undesirable acceptance, similar to 10% and 15% rice bran enriched cookies/biscuits, (see **Table 4**). These results agree with previous studies that reported a reduction in overall acceptance scores in enriched foods as the fibre incorporation increased [20, 45]. Contrastingly, the addition of 5% dietary fibre was acceptable based on sensory evaluation results in wheat bran enriched biscuits. Evidence suggests that rice bran significantly ($p < 0.05$) enhanced the thickness of cookies/biscuits, however, other physical qualities such as width and spread factor (SF%) showed no significant differences ($p > 0.05$), (see **Table 5**). Similar, findings were reported in some other fibre supplementation studies conducted. This can be as a result of the enhanced moisture absorption capacity of the dietary fibre used in the enriched cookies. In a recent study, Vijerathna et al. [38] reported that the enhanced size of the hydrophilic starch granules increased the thickness of fibre enriched cookies.

Corn fibre supplemented cookies displayed desirable overall acceptance at 20% incorporation rate and was significantly different ($p < 0.05$) in comparison to control cookies/biscuits, as a result, enriched corn fibre cookies/biscuit obtained the highest sensory score, (see **Table 6**). This suggests that corn fibre can be incorporated at a higher rate and produced desirable results possibly due to its high water retention capacity and its particle. In previous studies, Mishra & Chandra [57] reported a similar trend in results using a higher incorporation rate in cookies/biscuits. Similarly, supplementation of cookies/biscuits at 10% and 20% were significantly different ($p < 0.05$) to control, 20% corn fibre cookies/biscuits followed by 10% supplemented corn fibre cookies/biscuits obtained the best scores during panel sensory evaluation. This desirable overall acceptance at 10% - 20% incorporation may have been influenced by cookies/biscuits increase moistures that facilitated texture 1.8 ± 0.5 (Kg Force) and 1.9 ± 0.4 (Kg Force) at 10% and 20% respectively; and colour of the enriched product. Cookies/biscuits incorporated with corn fibre at 30% obtained the lowest overall acceptance score. This suggests that increased firmness and other sensory attributes such as flavour, colour, appearance and texture acceptance which were significantly undesirable ($p < 0.05$) based on sensory panel evaluation contributed to a low overall acceptance of the food product.

In terms of physical parameters, results suggest that the firmness of corn fibre enriched cookies/biscuits increased with increasing incorporation of corn fibre up to 30%. Jia et al. [58] indicated that water-insoluble proteins in flours that possessed minimal gluten, namely glutenin and gliadin combined to influence elasticity and structural strength of dough (glutenin) and viscosity and fluidity of dough (gliadin) tend to intertwine and formed a strong protein network structure in the food matrix. This suggests that the degree of firmness affected the protein network in the food matrix negatively possibly due to low moisture levels which contributed greatly to the high texture of the cookies/biscuits [52]. Cookies/biscuits (51.9 ± 5.0 mm) supplemented at 30% were thicker than the control (49.1 ± 24.5), however, there was no significant differences ($p > 0.05$), (see **Table 7**). This can be attributed to the high moisture absorption capacity of corn fibre, a satisfactory source of arabinoxylan dietary fibre which possibly clings to the bound water within the food matrix network, as the viscosity of the solution rises in the food system, leaving the protein components to form strong aggregates. The polysaccharide, arabinoxylan tends to possess various physicochemical properties, such as the high capacity to retain water and display an inclination to form high viscosity solutions when incorporated into the food matrix [22].

Incorporation of rice bran into bread at 15% showed a significant undesirable overall acceptance ($p < 0.05$) in comparison to control samples for all sensory attributes, except crust colour, (see **Table 8**). This can be attributed to a possible darker crumb in comparison to the control. Ortiz de Erive, Wang, He, and Chen [52] indicated that due to the enrichment of bread with dietary fibre their colour is likely to be darker in comparison to the non-enriched sample, as a result of the lower baking temperature of the crumb, thus affecting caramelization or Maillard's reaction. Arabinoxylans significantly affected protein network formation influencing the food matrix features and aroma of incorporated food products [59]. The aroma of enriched bread up to 10% was significantly different ($p < 0.05$) from the control. Enriched rice bran at 15% obtained the lowest overall acceptance score by the sensory evaluation panellists. In other studies, rice bran enriched bread was found to be acceptable at 5–10% [55]. This may be due to the sensory panel members' dietary familiarity with wheat flour bread. There was no significant difference ($p > 0.05$) in the specific volume (ml/g) between enriched rice bran bread and the control, however, specific volume reduced as rice bran incorporation percentage increase in the enriched bread sample, (see **Table 9**). This can be attributed to the water absorption capacity of the rice bran, which absorbs potentially most of the moisture, its ability to form viscous solutions, thus leaving the gluten component in the bread matrix inadequately hydrated. Pauline et al. [48] reported that rice bran enriched showed a lower specific volume in comparison to the enriched bread. Moreover, as rice bran is being incorporated into the enriched bread, due to the high-water capacity of rice bran, the enriched bread texture is likely to increase and become denser and less porous, thus resulting in the continual reduction of the specific volume from 10.7 ± 9.1 at 0% rice bran incorporation to 9.8 ± 6.6 at 10% rice bran incorporation [52]. It can be suggested that textural qualities of bread tend tends to be affected by its moisture content.

Corn bran enriched cakes up to 20% fibre incorporation displayed significantly ($p < 0.05$) more desirable sensory qualities than control cakes, (see **Table 10**). This can be attributed to the increased moisture content levels caused by the addition of corn bran during the enrichment process, which allowed the corn bran supplemented cakes to be adequately hydrated. There was a significant difference in crust colour of corn bran enriched cakes and control at the 20% fibre incorporation level. This can be attributed to the possible pale colour of the enriched cakes at the 20% level of fibre incorporation. Generally, dietary fibre enriched cakes take the inherent colour of the fibre being utilised in the process of enrichment, until Maillard's reaction occurs [52]. The increasing levels of corn bran replacement in cake batter showed no influence on the hardness and springiness of cakes [23]. In terms of physical qualities, the firmness of cakes increased incrementally with the increase in corn bran supplementation, (see **Table 11**). Moreover, there was no significant difference ($p < 0.05$) in physical qualities, except in crust L^* at 25% and 30% enrichment. This can be attributed to the possible darker colour of the corn bran enriched cakes crust in comparison to the control. The high baking temperature will tend to affect the fibre enriched cakes' crust due to caramelization or Maillard's reaction and the inherent colour of the fibre [52]. In summary, the incorporation of dietary fibres, rice bran and sugarcane bagasse affected the sensory and physical qualities of baked food products unfavourably. However, corn fibre and corn bran produced desirable sensory and physical effects at 20% fibre supplementation in both cookies/biscuits and cakes.

4.3 Beneficial implications of dietary fibres in foods

4.3.1 Nutritive value of enriched foods

The fundamental evidence of this review suggests that as the level of fibre incorporation increased the nutritive value of the food products cookies/biscuits, bread and cakes were significantly ($p < 0.05$) enhanced, resulting in increased moisture, ash, protein, minerals, vitamins, dietary fibres and crude fats, essentially in cereal-based incorporated food products. Corn bran enriched bread was suggested to contain significant ($p < 0.05$) contents of phytic acid contents. More recently, Ekpa, Palacios-Rojas, Kruseman, Fogliano, & Linnemann [4] indicated that food enrichment is an essential processing technique to enhance the nutrient content of staple foods including baked food products, thus, this suggests that fibre enriched foods can potentially provide convenience to consumers and ultimately facilitates improved food nutrition guidelines for the society and foster food security locally. Similarly, rice bran possessed vital antioxidants, which comprised of the well-recognised immune system enhancing compound, namely phytosterols; polysaccharides; minerals and trace minerals including magnesium, selenium, zinc, vitamin E, omega-3 fatty acids and many other phytonutrients [28]. This suggests that the strategy of fibre enrichment of popular food products can potentially be utilised more widely by stakeholders in the food industry in collaboration with health care agencies of various age groups, stakeholders of feeding programmes in schools and policymakers in governmental public health agencies. In another recent study, corn fibre was found to be an effective antioxidant than wheat bran and this was attributed to its elevated ferulic acid content and polyamine-conjugates. Interestingly, hydroxycinnamates may not be necessary for the antioxidant effect [30]. Contrastingly, in sugarcane bagasse supplemented food products, there were instances of reduced total fat, protein and marginally increased in moisture content of food products. Reduction in protein and fats contents was also reported in other fibre supplementation research [60]. Overall, the nutritive value of food products can be enhanced by fibre enrichment.

4.3.2 Health benefits

It has been widely established that numerous health benefits are associated with the consumption of enriched food products in recommended administered quantities. Moreover, dietary fibre potentially can contribute to several health benefits such as enhanced bowel function, reduced levels of cholesterol in the body, better weight maintenance and assisted in controlling blood sugar levels in the human body [24]. Chen et al. [5] indicated that there are several beneficial impacts on various physiological processes which can be attributed to arabinoxylans and consequently health functions and prebiotic effects are being influenced by arabinoxylans structures, which in turn depends on its method of extraction and source. This suggests that rice bran, corn fibre and sugarcane bagasse, which are well-established sources of dietary fibre arabinoxylans, can potentially be utilised to produce a wider range of enriched foods which can confer various types of health benefits to the consumers. However, the consumption of dietary fibre should adhere to the established guideline of at least 25 g/day for adults [6].

Dietary fibre supplemented foods with rice bran, corn fibre and sugarcane bagasse, namely cookies/biscuits, bread and cakes enriched foods was significantly ($p < 0.05$) higher in nutritive value, and contrastingly tend to contain significantly ($p < 0.05$) reduced energy value (Kcal/100 g) in comparison to control samples. Evidence suggests that fibre enriched cookies/biscuits, bread and cakes were significantly enhanced ($p < 0.05$) by supplementation, thus they can be considered potentially as functional foods. Moreover, further evidence indicated that supplementation of chapatti using sugarcane bagasse resulted in enhanced total fibre $7.4 \pm 0.5–11.7 \pm 0.6$ g/100 g and contributed to elevated inhibition activity of the 2–2 diphenyl-1 picrylhydrazyl (DPPH) free radical values. Diets with enhanced fibre contents are associated with desirable effects on the health of consumers [3]. In general, fibre enriched food products have shown a reduction in energy levels in comparison to the control samples. This suggests that enriched foods can be used for individuals with varying health conditions and risk factors such as coeliac patients and other different target groups.

4.3.3 Food policy

Dietary fibre enriched foods can potentially be utilised in various governmental-based food policies. Recently, Lockyer and Spiro [61] reported that the average fibre intake in the United Kingdom can be considered fairly below the level recommended level. This suggests that a fibre enrichment strategy involving the relevant stakeholders can potentially facilitate an improvement in dietary fibre intake within the population. Previously, a comprehensive review study was conducted for modern dietary and policy priorities for cardiovascular diseases, obesity, and diabetes and found that there are complex influences of different foods on long-term weight regulation and recommended implementing an evidence-based strategy, including policy approaches, for lifestyle changes [62]. Importantly, fibre enriched foods contain rice bran, corn fibre or sugarcane bagasse all can be used in producing functional foods suitable for the particular health setting, thus this indicates enriched foods can be utilised in different food policies with different outcomes.

4.3.4 Consumer acceptance

Despite, the promising nutritional enhancement of enriched food products, rice bran and sugarcane bagasse at increasing incorporation levels tend to be associated with undesirable sensory and physical qualities of baked foods [55]. Evidence of this review suggests that lower incorporation rates can potentially result in improved overall acceptance of fibre enriched food products, further results suggest that the level of overall acceptance of baked products cookies/biscuits, bread and cakes were considered unacceptable above 20% incorporation for rice bran and sugarcane bagasse any type particular baked product. In support of evidence, [39] stated that incorporation of wheat flour using 10% rice bran protein concentrate (RBPC) resulted in the production of protein-enriched biscuits with favourable overall acceptability. It can be suggested that consumers tend to have a potentially better awareness of the health benefits of dietary fibre enriched foods, and also some of the most popular products are being enriched with dietary fibre thus creating a potential health trend among consumers. Similarly, Gul, Yousuf, Singh, Singh, & Wani [32] stated that consumer's attitude towards healthy foods is improving and thus presents potential opportunities for further development of functional foods on the world markets. This suggests dietary fibre food ingredients can potentially find wide applications in the other fields, thus increasing consumer awareness of dietary fibre enriched foods. In summation, using popular foods such as enriched bread and other potentially widely consumed food products as the benchmark for the enrichment of other products can facilitate further acceptance of consumers.

4.4 Limitations of study

There were three (3) main limitations that were experienced in the conduct of this review, namely the framework of the search strategy which influenced the availability of an adequate number and relevant primary research articles relating to the incorporation of sugarcane bagasse in baked food products such as cookies/biscuits, bread and cakes; the appropriateness of primary research articles to meet the selection criteria for inclusion in the review for analysis and the high percentage of primary research articles relating to dietary fibre supplementation in baked foods originating from predominantly less developed and developing countries based in Asia such as India, Pakistan, Bangladesh, Malaysia, Iran and Sri Lanka. The framework of the search strategy returned a relatively high percentage of primary research relating to wheat bran incorporation in foods, other cereal fibres such as barley, rye and oats, fibres from fruits and vegetable parts among others. Approximately less than 5% of the primary research articles were related to the incorporation of sugarcane bagasse in baked foods.

The appropriateness of primary research articles to meet the selection criteria for inclusion in the review for analysis resulted in some potentially interesting primary research studies not being include in the review, namely [7, 35, 59, 63]. Moreover, some of these studies was unable to be placed into sub-groups to facilitate statistical analysis such as [44, 48, 49] among others and therefore there were excluded from the list of included studies of the review. Moreover, primary research studies which utilised arabinoxylan extract as the source of incorporation in baked foods were extremely minimal, namely [35, 63], however both failed to achieved the selection criteria and thus were not selected. Therefore, the analysis of studies with arabinoxylan extract supplemented at a lower percentage was not possible.

The majority of primary research articles originated from developing and less developing countries located in Asia such as [20, 37–39, 45] among others. Thus, studies were able to be analysed from a wider cross-section of laboratory settings.

5. Conclusion

This systematic review demonstrates the utilisation of a comprehensive research methodology in the selection and examination of fourteen (14) dietary fibre food supplementation primary research studies to provide relevant and impartial new insights of the effects of the incorporation of dietary fibre derived from selected cereals (rice bran and corn fibre) and sugarcane bagasse on the physical and sensory qualities of baked food products: cookies/biscuits, bread and cakes. Arabinoxylans-based dietary fibre sources' roles in food supplementation involves enhancing the nutritive value of ordinary food products; influencing the end quality of baked foods and potentially improving the sensory and physical qualities of baked foods. The supplementation of sugarcane bagasse at both 5% and 10% and rice bran up to 15% into cookies/biscuits resulted in significantly undesirable acceptance ($p < 0.05$). Corn fibre was supplemented into cookies/biscuits up to 20% and had a favourably significant ($p < 0.05$) impact on its sensory qualities. It was suggested that enhance moisture content from corn fibre incorporation in combination with its particle size contributed to this desirable outcome.

Sugarcane bagasse incorporation negatively affected the physical qualities of cookies/biscuits. The incremental addition of sugarcane bagasse resulted in a 50% rise in the firmness of 10% enriched cookies/biscuits, from 5.7 ± 5.4 (Kg Force) to 13.0 ± 3.9 (Kg Force). Rice bran significantly increase ($p < 0.05$) the thickness of cookies/biscuits, from 8.6 ± 1.0 (mm) to 9.9 ± 0.3 (mm), the width and spread factor were similar to control. Corn fibre cookies supplementation did not significantly affect its physical qualities. Rice bran incorporation into bread at 15% showed a significant ($p < 0.05$) undesirable effect on its sensory qualities. However, the was no significant adverse effect on its physical quality. Corn bran enriched cakes up to 20% fibre incorporation displayed a significant ($p < 0.05$) favourable effect on the sensory properties of cakes; contrastingly, it resulted in a significant undesirable physical effect on the crust colour of corn bran enriched cakes.

There were four (4) main beneficial implications of dietary fibre food fortification using rice bran, corn fibre and sugarcane bagasse, namely the evidence suggests the enhancement of the nutritive value of foods; allows for the potential production of fibre enrichment foods to cater for particular target groups; dietary fibre enriched foods can be utilised in various food policies with particular outcomes, such as increasing the fibre intake within the population and using enriched breads and other potentially widely consumed food products as the benchmark for enrichment of other products can facilitate further acceptance consumers. Future research should assess the effects of derived arabinoxylans from selected cereal fibres (rye, sorghum, rice and corn) and energy crop sugarcane fibres on the rheological, sensory and physical effects in muffins production. Updated and accurate rheological properties food supplementation data is important for the food industry.

Author details

Roy Orain Porter
Guyana Food Safety Authority, Ministry of Agriculture, Georgetown, Guyana

*Address all correspondence to: star.troy@yahoo.com

References

[1] Alan, P. A., Ofelia, R. S., Patricia, T., & Maribel, R. S. R. (2012). Cereal bran and wholegrain as a source of dietary fibre: technological and health aspects. *International Journal of Food Sciences and Nutrition, 63*(7), 882-892. https://doi.org/10.3109/09637486.2012.676030

[2] Aydogdu, A., Sumnu, G., & Sahin, S. (2018). Effects of addition of different fibers on rheological characteristics of cake batter and quality of cakes. *Journal of food science and technology, 55*(2), 667-677. https://doi.org/10.1007/s13197-017-2976-y

[3] Dhingra, D., Michael, M., Rajput, H., & Patil, R. T. (2012). Dietary fibre in foods: a review. *Journal of Food Science and Technology, 49*(3), 255-266. https://doi.org/10.1007/s13197-011-0365-5

[4] Ekpa, O., Palacios-Rojas, N., Kruseman, G., Fogliano, V., & Linnemann, A. R. (2019). Sub-Saharan African Maize-Based Foods - Processing Practices, Challenges and Opportunities. *Food Reviews International, 35*(7), 609-639. https://doi.org/10.1080/87559129.2019.1588290

[5] Chen, Z., Li, S., Fu, Y., Li, C., Chen, D., & Chen, H. (2019). Arabinoxylan structural characteristics, interaction with gut microbiota and potential health functions. *Journal of Functional Foods, 54*, 536-551. https://doi.org/10.1016/j.jff.2019.02.007

[6] European Food Safety Authority Panel on Dietetic Products, N., & Allergies. (2010). Scientific Opinion on Dietary Reference Values for carbohydrates and dietary fibre. EFSA Journal, 8(3), 1462. https://doi.org/10.2903/j.efsa.2010.1462

[7] Li, W., Hu, H., Wang, Q., & Brennan, C. S. (2013). Molecular Features of Wheat Endosperm Arabinoxylan Inclusion in Functional Bread. *Foods (Basel, Switzerland), 2*(2), 225-237. https://doi.org/10.3390/foods2020225

[8] Scientific Advisory Committee on Nutrition (2015). *SACN carbohydrates and health report*. Retrieved from https://www.gov.uk/government/publications/sacn-carbohydrates-and-health-report

[9] Buttriss, J. L. (2015). Fibre - Need to increase intake according to new recommendations. *Nutrition Bulletin, 40* (4), 291-295. https://doi.org/10.1111/nbu.12174

[10] European Commission. (2020). *Dietary fibres*. European Commission. Retrieved September 1, 2020 from https://ec.europa.eu/jrc/en/health-knowledge-gateway/promotion-prevention/nutrition/fibre

[11] World Health Organisation. (2020). The Ottawa Charter for Health Promotion. World Health Organisation. Retrieved September 1, 2020 from https://www.who.int/health promotion/conferences/previous/ottawa/en/index1.html

[12] Shahbandeh, M. (2019). Size of the global dietary fibers market from 2018 to 2025. Statista. Retrieved August 18, 2020 from https://www.statista.com/statistics/1053431/dietary-fibers-market-value-global

[13] Foschia, M., Peressini, D., Sensidoni, A., & Brennan, C. S. (2013). The effects of dietary fibre addition on the quality of common cereal products. *Journal of Cereal Science, 58*(2), 216-227. https://doi.org/10.1016/j.jcs.2013.05.010

[14] Casas, G. A., Lærke, H. N., Bach Knudsen, K. E., & Stein, H. H. (2019). Arabinoxylan is the main polysaccharide in fiber from rice

coproducts, and increased concentration of fiber decreases in vitro digestibility of dry matter. *Animal Feed Science and Technology, 247*, 255-261. https://doi.org/10.1016/j.anifeedsci.2018.11.017

[15] Fadel, A., Mahmoud, A. M., Ashworth, J. J., Li, W., Ng, Y. L., & Plunkett, A. (2018). Health-related effects and improving extractability of cereal arabinoxylans. *International journal of biological macromolecules, 109*, 819-831. https://doi.org/10.1016/j.ijbiomac.2017.11.055

[16] Dimopoulou, M., & Kontogiorgos, V. (2020). Soluble dietary fibres from sugarcane bagasse. *International Journal of Food Science & Technology, 55*(5), 1943-1949. https://doi.org/10.1111/ijfs.14445

[17] Haghighi-Manesh, S., & Azizi, M. H. (2018). Integrated extrusion-enzymatic treatment of corn bran for production of functional cake. *Food science & nutrition, 6*(7), 1870-1878. https://doi.org/10.1002/fsn3.738

[18] Yadav, M. P., Kale, M. S., Hicks, K. B., & Hanah, K. (2017). Isolation, characterization and the functional properties of cellulosic arabinoxylan fiber isolated from agricultural processing by-products, agricultural residues and energy crops. *Food Hydrocolloids, 63*, 545-551. https://doi.org/10.1016/j.foodhyd.2016.09.022

[19] Bultum, L. E., Emire, S. A., & Wolde, Y. T. (2020). Influence of full fat rice bran from Ethiopian rice milling industries on nutritional qualities, physicochemical and sensory properties of bread and biscuits. *Journal of Food Measurement and Characterization, 14*(4), 2253-2261. https://doi.org/10.1007/s11694-020-00472-7

[20] Javaria, S. (2017). Formulation and quality evaluation of aglutenics biscuits supplimented with rice bran for coeliac patients. *Pure and Applied Biology, 6*. https://doi.org/10.19045/bspab.2017.600137

[21] Mena, B., Fang, Z., Ashman, H., Hutchings, S., Ha, M., Shand, P. J., & Warner, R. D. (2020). Influence of cooking method, fat content and food additives on physicochemical and nutritional properties of beef meatballs fortified with sugarcane fibre. *International Journal of Food Science & Technology, 55*(6), 2381-2390. https://doi.org/10.1111/ijfs.14482

[22] Rosicka-Kaczmarek, J., Komisarczyk, A., Nebesny, E., & Makowski, B. (2016). The influence of arabinoxylans on the quality of grain industry products. *European Food Research and Technology, 242*(3), 295-303. https://doi.org/10.1007/s00217-015-2549-0

[23] Singh, M., Liu, S. X., & Vaughn, S. F. (2012). Effect of corn bran as dietary fiber addition on baking and sensory quality. *Biocatalysis and Agricultural Biotechnology, 1*(4), 348-352. https://doi.org/10.1016/j.bcab.2012.02.005

[24] Jarosław Wyrwisz, M. K. (2015). The Application of Dietary Fiber in Bread Products. Journal of Food Processing & Technology, 06(05). https://doi.org/10.4172/2157-7110.1000447

[25] Ozturk, O. K., & Mert, B. (2018). The effects of microfluidization on rheological and textural properties of gluten-free corn breads. *Food Research International, 105*, 782-792. https://doi.org/10.1016/j.foodres.2017.12.008

[26] Sairam, S., Krishna, A. G. G., & Urooj, A. (2011). Physico-chemical characteristics of defatted rice bran and its utilization in a bakery product. *Journal of Food Science and Technology-Mysore, 48*(4), 478-483. https://doi.org/10.1007/s13197-011-0262-y

[27] Mendis, M., Leclerc, E., & Simsek, S. (2016). Arabinoxylans, gut

microbiota and immunity. *Carbohydrate polymers, 139*, 159-166. https://doi.org/10.1016/j.carbpol.2015.11.068

[28] Park, H.-Y., Lee, K.-W., & Choi, H.-D. (2017). Rice bran constituents: immunomodulatory and therapeutic activities. *Food & Function, 8*(3), 935-943. https://doi.org/10.1039/c6fo01763k

[29] Phimolsiripol, Y., Mukprasirt, A., & Schoenlechner, R. (2012). Quality improvement of rice-based gluten-free bread using different dietary fibre fractions of rice bran. *Journal of Cereal Science, 56*(2), 389-395. https://doi.org/10.1016/j.jcs.2012.06.001

[30] Bauer, J. L., Harbaum-Piayda, B., Stöckmann, H., & Schwarz, K. (2013). Antioxidant activities of corn fiber and wheat bran and derived extracts. LWT - Food Science and Technology, 50(1), 132-138. https://doi.org/10.1016/j.lwt.2012.06.012

[31] Begum, R., Ahmed, S., Hakim, M., & Sen, J. (2019). Comparative Study among Composite Breads Incorporated with Full Fatted and Defatted Rice Bran. *Journal of Environmental Science and Natural Resources, 11*(1-2), 43-52. https://doi.org/10.3329/jesnr.v11i1-2.43364

[32] Gul, K., Yousuf, B., Singh, A. K., Singh, P., & Wani, A. A. (2015). Rice bran: Nutritional values and its emerging potential for development of functional food—A review. *Bioactive Carbohydrates and Dietary Fibre, 6*(1), 24-30. https://doi.org/10.1016/j.bcdf.2015.06.002

[33] Hussein, A., & Ibrahim, G. (2019). Effects of various brans on quality and volatile compounds of bread. *Foods and Raw Materials, 7*, 35-41. https://doi.org/10.21603/2308-4057-2019-1-42-50

[34] Rose, D. J., Inglett, G. E., & Liu, S. X. (2010). Utilisation of corn (*Zea mays*) bran and corn fiber in the production of food components. *Journal of the Science of Food and Agriculture, 90*(6), 915-924. https://doi.org/10.1002/jsfa.3915

[35] Koegelenberg, D., & Chimphango, A. F. A. (2017). Effects of wheat-bran arabinoxylan as partial flour replacer on bread properties. *Food Chemistry, 221*, 1606-1613. https://doi.org/10.1016/j.foodchem.2016.10.130

[36] Sandhu, P., Bains, K., Singla, G., & Sangwan, R. (2018). Utilization of Corn Fibre and Pectin Gel for the Development of Low Calorie and High Fibre Biscuits. *Current Journal of Applied Science and Technology, 25*(5), 1-9. https://doi.org/10.9734/cjast/2017/38966

[37] Sangeetha, A. V., Mahadevamma, S., Begum, K., & Sudha, M. L. (2011). Influence of processed sugarcane bagasse on the microbial, nutritional, rheological and quality characteristics of biscuits. *International Journal of Food Sciences and Nutrition, 62*(5), 457-464. https://doi.org/10.3109/09637486.2010.549819

[38] Vijerathna, M. P. G., Wijesekara, I., Perera, R., Maralanda, S. M. T. A., Jayasinghe, M., & Wickramasinghe, I. (2019). Physico-chemical Characterization of Cookies Supplemented with Sugarcane Bagasse Fibres. *Vidyodaya Journal of Science, 22*(1), 29. https://doi.org/10.4038/vjs.v22i1.6062

[39] Yadav, R. B., Yadav, B. S., & Chaudhary, D. (2011). Extraction, characterization and utilization of rice bran protein concentrate for biscuit making. *British Food Journal, 113*(9), 1173-1182. https://doi.org/10.1108/00070701111174596

[40] Zhang, L., Van Boven, A., Mulder, J., Grandia, J., Chen, X. D., Boom, R. M., & Schutyser, M. A. I. (2019). Arabinoxylans-enriched fractions: From

dry fractionation of wheat bran to the investigation on bread baking performance. *Journal of Cereal Science, 87*, 1-8. https://doi.org/10.1016/j.jcs.2019.02.005

[41] Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred reporting items for systematic reviews and MetaAnalyses: The PRISMA statement. *PLoS Med 6*(7): e1000097. https://doi.org/10.1371/journal.pmed1000097

[42] Downs, S. H., & Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *Journal of epidemiology and community health, 52*(6), 377–384. https://doi.org/10.1136/jech.52.6.377

[43] Hooper, P., Jutai, J. W., Strong, G., & Russell-Minda, E. (2008). Age-related macular degeneration and low-vision rehabilitation: a systematic review. Canadian Journal of Ophthalmology, 43(2), 180-187. https://doi.org/10.3129/i08-001

[44] Gil-López, D. I. L., Lois-Correa, J. A., Sánchez-Pardo, M. E., Domínguez-Crespo, M. A., Torres-Huerta, A. M., Rodríguez-Salazar, A. E., & Orta-Guzmán, V. N. (2019). Production of dietary fibers from sugarcane bagasse and sugarcane tops using microwave-assisted alkaline treatments. *Industrial Crops and Products, 135*, 159-169. https://doi.org/10.1016/j.indcrop.2019.04.042

[45] Amna, Y., Bhatti, M. S., Anwaar, A., & Randhawa, M. A. (2011). Effect of rice bran supplementation on cookie baking quality. *Pakistan Journal of Agricultural Sciences, 48*(2), 133-138.

[46] Jauharah, M. Z., Wan Ishak, W. R., & Robert, S. (2014). Physicochemical and Sensorial Evaluation of Biscuit and Muffin Incorporated with Young Corn Powder. Sains Malaysiana, 43, 45-52.

[47] Ameh, M. O., Gernah, D. I., & Igbabul, B. D. (2013). Physico-Chemical and Sensory Evaluation of Wheat Bread Supplemented with Stabilized Undefatted Rice Bran. Food and Nutrition Sciences, 04(09), 43-48. https://doi.org/10.4236/fns.2013.49a2007

[48] Pauline, M., Roger, P., Sophie Natacha Nina, N. E., Arielle, T., Eugene, E. E., & Robert, N. (2020). Physico-chemical and nutritional characterization of cereals brans enriched breads. *Scientific African, 7*, e00251. https://doi.org/10.1016/j.sciaf.2019.e00251

[49] Silva, A. S., Correa, L. G., Kanai, R. S. S., & Shirai, M. A. (2020). Effect of sugarcane bagasse addition on physical, chemical, and sensory properties of oat flour and banana cake. *Journal of Texture Studies*. https://doi.org/10.1111/jtxs.12542

[50] European Food Safety Authority Panel on Dietetic Products, N., & Allergies. (2011). Scientific Opinion on the substantiation of health claims related to arabinoxylan produced from wheat endosperm and reduction of post-prandial glycaemic responses (ID 830) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. EFSA Journal, 9 (6), 2205. https://doi.org/10.2903/j.efsa.2011.2205

[51] Saeed, F., Pasha, I., Anjum, F. M., & Sultan, M. T. (2011). Arabinoxylans and Arabinogalactans: A Comprehensive Treatise. Critical Reviews in Food Science and Nutrition, 51(5), 467-476. https://doi.org/10.1080/10408391003681418

[52] Ortiz de Erive, M., Wang, T., He, F., & Chen, G. (2020). Development of high-fiber wheat bread using microfluidized corn bran. Food Chemistry, 310, 125921. https://doi.org/10.1016/j.foodchem.2019.125921

[53] Leang, Y. H., & Saw, H. Y. (2011). Proximate and functional properties of

sugarcane bagasse. *Agro Food Industry Hi-Tech, 22*(2), 5-8.

[54] Kale, M. S., Pai, D. A., Hamaker, B. R., & Campanella, O. H. (2010). Structure-function relationships for corn bran arabinoxylans. *Journal of Cereal Science, 52*(3), 368-372. https://doi.org/10.1016/j.jcs.2010.06.010

[55] Zidan, N., & Eldemery, M. (2016). Utilization of defatted black rice bran in wheat bread preparation for enhancing nuritional and functional properties. *Journal of Food and Dairy Sciences, 7*(2), 107-117. https://doi.org/10.21608/jfds.2016.42819

[56] Sozer, N., Cicerelli, L., Heiniö, R.-L., & Poutanen, K. (2014). Effect of wheat bran addition on in vitro starch digestibility, physico-mechanical and sensory properties of biscuits. *Journal of Cereal Science, 60*(1), 105-113. https://doi.org/10.1016/j.jcs.2014.01.022

[57] Mishra, N., & Chandra, R. (2012). Development of functional biscuit from soy flour & rice bran. *International Journal of Agricultural and Food Science, 2*, 14-20.

[58] Jia, M., Yu, Q., Chen, J., He, Z., Chen, Y., Xie, J., . . . Xie, M. (2020). Physical quality and in vitro starch digestibility of biscuits as affected by addition of soluble dietary fiber from defatted rice bran. *Food Hydrocolloids, 99*, 105349. https://doi.org/10.1016/j.foodhyd.2019.105349

[59] Döring, C., Nuber, C., Stukenborg, F., Jekle, M., & Becker, T. (2015). Impact of arabinoxylan addition on protein microstructure formation in wheat and rye dough. *Journal of Food Engineering, 154*, 10-16. 10.1016/j.jfoodeng.2014.12.019

[60] El-Gammal, R., & El Kewawy, H. (2014). Effect of addition of stabilized rice bran on physical, rheological and chemical characteristics of pan bread. *Journal of Food and Dairy Sciences, 5*(11), 813-825. https://doi.org/10.21608/jfds.2014.53231

[61] Lockyer, S., & Spiro, A. (2020). The role of bread in the UK diet: An update. *Nutrition Bulletin, 45*(2), 133-164. https://doi.org/10.1111/nbu.12435

[62] Mozaffarian, D. (2016). Dietary and Policy Priorities for Cardiovascular Disease, Diabetes, and Obesity. *Circulation, 133*(2), 187-225. https://doi.org/10.1161/circulationaha.115.018585

[63] Ayala-Soto, F. E., Serna-Saldívar, S. O., & Welti-Chanes, J. (2017). Effect of arabinoxylans and laccase on batter rheology and quality of yeast-leavened gluten-free breads. *Journal of Cereal Science, 73*, 10-17. https://doi.org/10.1016/j.jcs.2016.11.003